

Memo version 0.5

# **CEPC Analysis Memo**

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3	Higgs boson decaying to ZZ* channel at the CEPC
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9 10	
12	Abstract
13	

15 <b>Contents</b>	
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16	1	Intro	oduction	4
17	2	Sam	ples	6
18		2.1	ZH Samples	6
19		2.2	Two fermions background Samples	8
20		2.3	Four fermions background Samples	9
21	3	Ana	lysis Procedure	11
22	4	Ever	It Selection of $Z(\rightarrow \mu\mu)H(ZZ^*\rightarrow \nu\nu qq)$	14
23		4.1	$Z(\rightarrow \mu^+\mu^-), H(Z\rightarrow\nu\bar{\nu}, Z^*\rightarrow q\bar{q})$	14
24			4.1.1 Event selection (Cut-based only)	14
25		4.2	$Z(\rightarrow \mu^+\mu^-), H(Z\rightarrow q\bar{q}, Z^*\rightarrow\nu\bar{\nu})$	20
26			4.2.1 Event selection (Cut-based only)	20
27	5	Ever	<b>it Selection of Z</b> ( $\rightarrow \nu \nu$ ) <b>H</b> ( <b>ZZ</b> * $\rightarrow \mu \mu qq$ )	28
28		5.1	$Z(\rightarrow \nu \bar{\nu}), H(ZZ^* \rightarrow \mu^+ \mu^- \rightarrow q\bar{q}) \ldots \ldots$	28
29			5.1.1 Event selection (Cut-based only)	28
30		5.2	$Z(\rightarrow \nu \bar{\nu}), H(Z \rightarrow q\bar{q}, Z^* \rightarrow \mu^+ \mu^-) \dots \dots$	34
31			5.2.1 Event selection (Cut-based only)	34
32	6	Ever	<b>it Selection of Z</b> ( $\rightarrow qq$ ) <b>H</b> ( <b>ZZ</b> * $\rightarrow \nu\nu\mu\mu$ )	42
33		6.1	$Z(\rightarrow q\bar{q}), H(Z\rightarrow\nu\bar{\nu}, Z^*\rightarrow\mu^+\mu^-)$	42
34			6.1.1 Event selection (Cut-based only)	42
35		6.2	$Z(\rightarrow q\bar{q}), H(Z\rightarrow \mu^+\mu^-, Z^*\rightarrow \nu\bar{\nu})$	49
36			6.2.1 Event selection (Cut-based only)	49
37	7	Resu	ılt	57
38		7.1	Final Higgs mass distributions and fitting results.	57
39			7.1.1 $\mu\mu\nu\nu qq$ channel	57
40			7.1.2 $\mu\mu qq v v$ channel	58
41			7.1.3 $vv\mu\mu qq$ channel	59
42			7.1.4 $\nu \nu q q \mu \mu$ channel	60
43			7.1.5 $qq\mu\mu\nu\nu$ channel	61

44		7.1.6 $qqvv\mu\mu$ channel	52
45	7.2	Calculations	53
46		7.2.1 Cut – based calculations	53

### 47 ChangeLog

#### 48 version 0.6

- Change some plot size etc. to make the pdf file after compiling in good order
- Update fitting results (both cut-based and BDT) for 5 channels
- Fill the structure with plots/tables for each channel ( " $\mu\mu$ ", " $\nu\nu$ ", "qq" channels )

#### 52 version 0.5

- Update(add) author information
- Change the section numbering so as to start it from the introduction.
- Update the references which was not working, in the introduction section
- Add "Analysis Procedure" section. Add general desription about our analysis framework.
- Make a structure for each channel ( " $\mu\mu$ ", " $\nu\nu$ ", "qq" channels )

#### 58 Version 0.4

• Display the result of hvvjj channel

#### 60 Version 0.4.1

• Add pictures of signal's cut conditions

#### 62 Version 0.4.2

• Add background distribution

#### 64 Version 0.4.2

• change samples and update pictures and cut flow table

#### 66 Version 0.4.3

• 3/19/2019: 1.Update sample table, cut flow table and histograms, now the background in histograms are 2f, 4f and ZH. 2.Add present state of hjjvv channel.

#### 69 Version 0.4.4

• 4/25/2019: 1.Update results. 2. add equations for calculation

### 71 Version 0.1.0

• 5/10/2019: 1.Add introduction. 2. Add more for calculation part

#### 73 **1** Introduction

The historic discovery of a Higgs boson in 2012 by the ATLAS and CMS collaborations [1, 2] at the 74 Large Hadron Collider (LHC) has opened a new era in particle physics. Subsequent measurements of the 75 properties of the new particle have indicated compatibility with the Standard Model (SM) Higgs boson [3, 76 4, 5, 6, 7, 8, 9]. While the SM has been remarkably successful in describing experimental phenomena, it 77 is important to recognize that it is not a complete theory. In particular, it does not *predict* the parameters 78 in the Higgs potential, such as the Higgs boson mass. The vast difference between the Planck scale 79 and the weak scale remains a major mystery. There is not a complete understanding of the nature of 80 electroweak phase transition. The discovery of a spin zero Higgs boson, the first elementary particle of 81 its kind, only sharpens these questions. It is clear that any attempt of addressing these questions will 82 involve new physics beyond the SM (BSM). Therefore, the Higgs boson discovery marks the beginning 83 of a new era of theoretical and experimental explorations. 84

A physics program of the precision measurements of the Higgs boson properties will be a critical component of any road map for high energy physics in the coming decades. Potential new physics beyond the SM could lead to observable deviations in the Higgs boson couplings from the SM expectations. Typically, such deviations can be parametrized as

$$\delta = c \frac{v^2}{M_{\rm NP}^2},\tag{1}$$

where v and  $M_{\rm NP}$  are the vacuum expectation value of the Higgs field and the typical mass scale of new 89 physics, respectively. The size of the proportionality constant c depends on the model, but it should not 90 be much larger than O(1). The high-luminosity LHC (HL-LHC) will measure the Higgs boson couplings 91 to about 5% [10, 11]. At the same time, the LHC will directly search for new physics from a few hundreds 92 of GeV to at least one TeV. Eq. 1 implies that probing new physics significantly beyond the LHC reach 93 would require the measurements of the Higgs boson couplings at least at percent level accuracy. To 94 achieve such precision will need new facilities, a lepton collider operating as a Higgs factory is a natural 95 next step. 96

The Circular Electron-Positron Collider CEPC, proposed by the Chinese particle physics community, is one of such possible facilities. The CEPC will be placed in a tunnel with a circumference of approximately 100 km and will operate at a center-of-mass energy of  $\sqrt{s} \sim 240$  GeV, near the maximum of the Higgs boson production cross section through the  $e^+e^- \rightarrow ZH$  process. At the CEPC, in contrast to the LHC, Higgs boson candidates can be identified through a technique known as the recoil mass method without tagging its decays. Therefore, the Higgs boson production can be disentangled from its decay in a model independent way. Moreover, the cleaner environment at a lepton collider allows much better

exclusive measurements of Higgs boson decay channels. All of these give the CEPC an impressive reach 104 in probing Higgs boson properties. With the expected integrated luminosity of  $5.6 fb^{-1}$ , over one million 105 Higgs bosons will be produced. With this sample, the CEPC will be able to measure the Higgs boson 106 coupling to the Z boson with an accuracy of 0.25%, more than a factor of 10 better than the LHC. Such a 107 precise measurement gives the CEPC unprecedented reach into interesting new physics scenarios which 108 are difficult to probe at the LHC. The CEPC also has strong capability in detecting Higgs boson invisible 109 decay. It is sensitive to the invisible decay branching ratio down to 0.3%. In addition, it is expected to 110 have good sensitivities to exotic decay channels which are swamped by backgrounds at the LHC. It is 111 also important to stress that an  $e^+e^-$  Higgs factory can perform model independent measurement of the 112 Higgs boson width. This unique feature in turn allows for the model independent determination of the 113 Higgs boson couplings. 114

P.S. Above description given by Lineteng is almost the same as the first section of the CEPC whitepaper.(2019-12-08)

### 117 **2** Samples

The analysis is performed on MC samples simulated on the CEPC conceptual detector. Sample path:  $/cefs/data/DstData/CEPC240/CEPC_v4/$ , the details of samples is listed below, and the events expected is  $5600 fb^{-1}$ 

$uq:u,\bar{u}$	$up: u, \bar{u}, c, \bar{c}$	$nu_e: v_e, \overline{v}_e$
$dq:d,\bar{d}$	$down: d, \bar{d}, s, \bar{s}, b, \bar{b}$	$nu_{\mu}: \nu_{\mu}, \overline{\nu}_{\mu}$
$cq:c,\bar{c}$	$e:e^-,e^+$	$nu_{\tau}: v_{\tau}, \overline{v}_{\tau}$
$sq:s, \overline{s}$	$mu:\mu^-,\mu^+$	$nu_{\mu,\tau}:v_{\mu,\tau},\overline{v}_{\mu,\tau}$
$bq:b,ar{b}$	$tau: \tau^-, \tau^+$	$nu: v_{e,\mu,\tau}, \overline{v}_{e,\mu,\tau}$
$f:e^{-},\mu,\pi$	$\tau, \nu_e, \nu_\mu, \nu_\tau, u, d, c, s, b$	q:u,d,c,s,b

Table 1: The alias for particles

### 121 2.1 ZH Samples

ProcessCross sectionEvents expectedele1h_aa0.016190.24855ele1h_az0.010860.5394ele1h_bb4.0622758.33ele1h_cc0.2051149.1275ele1h_e2e20.001548.63247ele1h_e3e30.4452494.4475ele1h_gg0.6033380.1165ele1h_ss0.00.0ele1h_zz0.1861042.623e2e1h_aa0.015486.3247e2e2h_aa0.015486.3247e2e2h_az0.010458.2972e2e2h_e2e20.001488.29614e2e2h_e2e20.001488.29614e2e2h_gg0.583251.19e2e2h_ss0.00.0e2e2h_ss0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.015486.3247e3e3h_aa0.01648.29614e3e3h_aa0.016			
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$e1e1h_e3e3$ $0.445$ $2494.4475$ $e1e1h_gg$ $0.603$ $3380.1165$ $e1e1h_ss$ $0.0$ $0.0$ $e1e1h_sw$ $1.51$ $8464.305$ $e1e1h_zz$ $0.186$ $1042.623$ $e2e2h_aa$ $0.0154$ $86.3247$ $e2e2h_bb$ $3.91$ $21917.505$ $e2e2h_cc$ $0.197$ $1104.2835$ $e2e2h_c2e2$ $0.00148$ $8.29614$ $e2e2h_e2e2$ $0.00148$ $8.29614$ $e2e2h_e2e3$ $0.428$ $2399.154$ $e2e2h_gg$ $0.58$ $3251.19$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_xz$ $0.179$ $1003.3845$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_e2$ $0.00148$ $8.29614$ $e3e3h_e2a$ $0.196$ $1098.678$ $e3e3h_e2a$ $0.0103$ $57.73665$ $e3e3h_e2a$ $0.427$ $2393.5485$ $e3e3h_e3a$ $0.427$ $2393.5485$ $e3e3h_e3a$ $0.427$ $2393.5485$ $e3e3h_e2a$ $0.178$ $997.779$ $nh_aa$ $0.106$ $594.183$ $nh_aa$ $0.106$ $594.183$ $nh_aa$ $0.106$ $594.183$ $nh_aa$ $0.106$ $594.183$ $nh_aa$ $0.00$ $0.0$ $nh_bb$ $26.7$ $149666.85$ $nh_aa$ $0.00$ $0.0$ $nh_aa$ $0.00$ $0.0$ $nh_aa$ $0.00$ $0.0$ $nh_$	e1e1h_e2e2	0.00154	8.63247
e1e1h.gg $0.603$ $3380.1165$ $e1e1h.ss$ $0.0$ $0.0$ $e1e1h.ww$ $1.51$ $8464.305$ $e1e1h.zz$ $0.186$ $1042.623$ $e2e2h.aa$ $0.0154$ $86.3247$ $e2e2h.az$ $0.0104$ $58.2972$ $e2e2h.bb$ $3.91$ $21917.505$ $e2e2h.cc$ $0.197$ $1104.2835$ $e2e2h.ce22$ $0.00148$ $8.29614$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.ss$ $0.0$ $0.0$ $e2e2h.ss$ $0.0$ $0.0$ $e2e2h.zz$ $0.179$ $1003.3845$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0103$ $57.73665$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ss$ $0.0$ $0.0$ $mh.aa$ $0.106$ $594.183$ $mh.ab$ $26.7$ $149666.85$ $mh.cc$ $1.35$ $7567.425$ $nh.e3e3$ $2.93$ $16424.115$ $nh.gg$ $3.97$ $22253.835$	e1e1h_e3e3	0.445	2494.4475
e1e1h.ss $0.0$ $0.0$ $e1e1h.zz$ $0.186$ $1042.623$ $e2e2h.aa$ $0.0154$ $86.3247$ $e2e2h.aa$ $0.0104$ $58.2972$ $e2e2h.bb$ $3.91$ $21917.505$ $e2e2h.cc$ $0.197$ $1104.2835$ $e2e2h.ce22$ $0.00148$ $8.29614$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.ss$ $0.0$ $0.0$ $e2e2h.zz$ $0.179$ $1003.3845$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0103$ $57.73665$ $e3e3h.aa$ $0.0103$ $57.73665$ $e3e3h.aa$ $0.0103$ $57.73665$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ss$ $0.0$ $0.0$ $nh.aa$ $0.106$ $594.183$ $nh.aa$ $0.106$ $594.183$ $nh.aa$ $0.0708$ $396.8694$ $nh.bb$ $26.7$ $149666.85$ $nh.cc$ $1.35$ $7567.4255$ $nh.e3e3$ $2.93$ $16424.115$ $nh.gg$ $3.97$ $22253.835$ $nh.ss$ $0.0$ $0.0$ $nh.$	e1e1h_gg	0.603	3380.1165
$e1e1h_xw$ $1.51$ $8464.305$ $e1e1h_zz$ $0.186$ $1042.623$ $e2e2h_aa$ $0.0154$ $86.3247$ $e2e2h_az$ $0.0104$ $58.2972$ $e2e2h_bb$ $3.91$ $21917.505$ $e2e2h_cc$ $0.197$ $1104.2835$ $e2e2h_e2e2$ $0.00148$ $8.29614$ $e2e2h_e3e3$ $0.428$ $2399.154$ $e2e2h_e3e3$ $0.428$ $2399.154$ $e2e2h_gg$ $0.58$ $3251.19$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_xz$ $0.179$ $1003.3845$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.016$ $594.183$ $nh_a$ $0.106$ $594.183$ $nh_a$ $0.106$ $594.183$ $nh_a$ $0.106$ $594.183$ $nh_e2e2$ $0.0101$ $56.61555$ <	e1e1h_ss	0.0	0.0
$e1e1h_zz$ 0.1861042.623 $e2e2h_aa$ 0.015486.3247 $e2e2h_az$ 0.010458.2972 $e2e2h_bb$ 3.9121917.505 $e2e2h_cc$ 0.1971104.2835 $e2e2h_e2e2$ 0.001488.29614 $e2e2h_e3e3$ 0.4282399.154 $e2e2h_gg$ 0.583251.19 $e2e2h_ss$ 0.00.0 $e2e2h_zz$ 0.1791003.3845 $e3e3h_aa$ 0.015486.3247 $e3e3h_aa$ 0.010357.73665 $e3e3h_bb$ 3.8921805.395 $e3e3h_c2e2$ 0.001488.29614 $e3e3h_e3e3$ 0.4272393.5485 $e3e3h_e3e3$ 0.4272393.5485 $e3e3h_e3e3$ 0.4272393.5485 $e3e3h_e3e3$ 0.4272393.5485 $e3e3h_ss$ 0.00.0 $e3e3h_ss$ 0.00.0 $e3e3h_ss$ 0.00.0 $e3e3h_ss$ 0.106594.183 $nnh_aa$ 0.106594.183 $nnh_aa$ 0.106594.183 $nnh_e2e2$ 0.010156.61555 $nnh_e3e3$ 2.9316424.115 $nnh_ss$ 0.00.0 $nnh_w$ 9.9555774.725 $nnh_aa$ 0.3121748.916 $qqh_aa$ 0.3121748.916 $qqh_aa$ 0.3121748.916 $qqh_aa$ 0.3121748.916 $qqh_e2e2$ 0.038168.165 $qqh_e3e3$ 8.6548487.575 $qqh_e3e3$ 8.6548487.575 <t< td=""><td>e1e1h_ww</td><td>1.51</td><td>8464.305</td></t<>	e1e1h_ww	1.51	8464.305
$e2e2h_aa$ $0.0154$ $86.3247$ $e2e2h_az$ $0.0104$ $58.2972$ $e2e2h_bb$ $3.91$ $21917.505$ $e2e2h_cc$ $0.197$ $1104.2835$ $e2e2h_e2e2$ $0.00148$ $8.29614$ $e2e2h_e3e3$ $0.428$ $2399.154$ $e2e2h_e3e3$ $0.00$ $0.0$ $e2e2h_x$ $0.179$ $1003.3845$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.0$ $0.0$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_e3e3$ $0.0708$ $396.8694$ $nh_aa$ $0.106$ $594.183$ $nh_aa$ $0.106$ $594.183$ $nh_e2e2$ $0.0101$ $56.61555$ $nh_e3e3$ $2.93$ $16424.115$ <tr< td=""><td>e1e1h_zz</td><td>0.186</td><td>1042.623</td></tr<>	e1e1h_zz	0.186	1042.623
e2e2h.az0.010458.2972 $e2e2h.bb$ 3.9121917.505 $e2e2h.cc$ 0.1971104.2835 $e2e2h.e2e2$ 0.001488.29614 $e2e2h.e3e3$ 0.4282399.154 $e2e2h.gg$ 0.583251.19 $e2e2h.gg$ 0.583251.19 $e2e2h.ss$ 0.00.0 $e2e2h.ss$ 0.00.0 $e2e2h.ss$ 0.1791003.3845 $e3e3h.aa$ 0.015486.3247 $e3e3h.aa$ 0.010357.73665 $e3e3h.bb$ 3.8921805.395 $e3e3h.cc$ 0.1961098.678 $e3e3h.e2e2$ 0.001488.29614 $e3e3h.e2e2$ 0.001488.29614 $e3e3h.e3e3$ 0.4272393.5485 $e3e3h.gg$ 0.5783239.979 $e3e3h.ss$ 0.00.0 $e3e3h.ss$ 0.00.0 $e3e3h.ss$ 0.00.0 $e3e3h.ss$ 0.00.0 $e3e3h.ss$ 0.00.0 $e3e3h.ss$ 0.00.0 $nh.aa$ 0.106594.183 $nh.bb$ 26.7149666.85 $nh.cc$ 1.357567.425 $nh.e2e3$ 2.9316424.115 $nh.gg$ 3.9722253.835 $nh.e3e3$ 2.9316424.115 $nh.gg$ 3.9722253.835 $nh.ss$ 0.00.0 $nh.ss$ 0.00.0 $nh.ss$ 0.2091171.5495 $qqh.aa$ 0.3121748.916 $qqh.aa$ 0.3121748.916<	e2e2h_aa	0.0154	86.3247
e2e2h.bb $3.91$ $21917.505$ $e2e2h.cc$ $0.197$ $1104.2835$ $e2e2h.e2e2$ $0.00148$ $8.29614$ $e2e2h.e3e3$ $0.428$ $2399.154$ $e2e2h.e3e3$ $0.428$ $2399.154$ $e2e2h.e3e3$ $0.428$ $2399.154$ $e2e2h.gg$ $0.58$ $3251.19$ $e2e2h.ss$ $0.0$ $0.0$ $e2e2h.ss$ $0.0$ $0.0$ $e2e2h.zz$ $0.179$ $1003.3845$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.aa$ $0.0103$ $57.73665$ $e3e3h.az$ $0.0103$ $57.73665$ $e3e3h.bb$ $3.89$ $21805.395$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.ss$ $0.0$ $0.0$ $nh.aa$ $0.106$ $594.183$ $nh.aa$ $0.106$ $594.183$ $nh.aa$ $0.0708$ $396.8694$ $nh.bb$ $26.7$ $149666.85$ $nh.cc$ $1.35$ $7567.4225$ $nh.e3e3$ $2.93$ $16424.115$ $nh.e3e3$ $2.93$ $16424.115$ $nh.e3e3$ $2.93$ $16424.135$ $nh.e3e3$ $2.93$ $16424.135$ <	e2e2h_az	0.0104	58.2972
$e2e2h\_e2e$ 0.001488.29614 $e2e2h\_e2e2$ 0.001488.29614 $e2e2h\_e3e3$ 0.4282399.154 $e2e2h\_gg$ 0.583251.19 $e2e2h\_gg$ 0.583251.19 $e2e2h\_xs$ 0.00.0 $e2e2h\_xs$ 0.1791003.3845 $e3e3h\_aa$ 0.015486.3247 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.01961098.678 $e3e3h\_e2e2$ 0.001488.29614 $e3e3h\_e3a$ 0.4272393.5485 $e3e3h\_e3a$ 0.4272393.5485 $e3e3h\_e3a$ 0.4272393.5485 $e3e3h\_e3a$ 0.4272393.5485 $e3e3h\_e3a$ 0.4272393.5485 $e3e3h\_ax$ 0.178997.779 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.000.0 $nnh\_ab$ 26.7149666.85 $nnh\_aca$ 0.000.0 $nnh\_ab$ 26.7149666.85 $nnh\_ac3$ 2.9316424.115 <td>e2e2h_bb</td> <td>3.91</td> <td>21917.505</td>	e2e2h_bb	3.91	21917.505
$e2e2h_e2e2$ $0.00148$ $8.29614$ $e2e2h_e3e3$ $0.428$ $2399.154$ $e2e2h_gg$ $0.58$ $3251.19$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_zz$ $0.179$ $1003.3845$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_aa$ $0.0103$ $57.73665$ $e3e3h_az$ $0.0103$ $57.73665$ $e3e3h_ac$ $0.196$ $1098.678$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_s$ $0.0$ $0.0$ $e3e3h_s$ $0.0$ $0.0$ $e3e3h_s$ $0.0$ $0.0$ $e3e3h_s$ $0.0$ $0.0$ $nh_a$ $0.106$ $594.183$ $nnh_a$ $0.106$ $594.183$ $nnh_a$ $0.106$ $594.183$ $nnh_s$ $0.0$ $0.0$ $nnh_s$ $0.00$ $0.0$ $nnh_s$ $0.03^8$ $168.165$ <t< td=""><td>e2e2h_cc</td><td>0.197</td><td>1104.2835</td></t<>	e2e2h_cc	0.197	1104.2835
$e2e2h_e3e3$ $0.428$ $2399.154$ $e2e2h_gg$ $0.58$ $3251.19$ $e2e2h_ss$ $0.0$ $0.0$ $e2e2h_ww$ $1.46$ $8184.03$ $e2e2h_zz$ $0.179$ $1003.3845$ $e3e3h_aa$ $0.0154$ $86.3247$ $e3e3h_az$ $0.0103$ $57.73665$ $e3e3h_az$ $0.0103$ $57.73665$ $e3e3h_az$ $0.0103$ $57.73665$ $e3e3h_az$ $0.0103$ $57.73665$ $e3e3h_az$ $0.196$ $1098.678$ $e3e3h_e2e2$ $0.00148$ $8.29614$ $e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_ag$ $0.578$ $3239.979$ $e3e3h_ss$ $0.0$ $0.0$ $e3e3h_ss$ $0.0$ $0.0$ $e3e3h_zz$ $0.178$ $997.779$ $nnh_aa$ $0.106$ $594.183$ $nnh_az$ $0.0708$ $396.8694$ $nnh_bb$ $26.7$ $149666.85$ $nnh_cc$ $1.35$ $7567.425$ $nnh_e3e3$ $2.93$ $16424.115$ $nnh_e3e3$ $2.93$ $16424.115$ $nnh_e3e3$ $2.93$ $16424.115$ $nnh_as$ $0.0$ $0.0$ $nnh_aa$ $0.312$ $1748.916$ $qqh_aa$ $0.312$ $1748.916$ $qqh_aa$ $0.312$ $1748.916$ $qqh_aa$ $0.312$ $1748$	e2e2h_e2e2	0.00148	8.29614
$e2e2h\_gg$ 0.583251.19 $e2e2h\_ss$ 0.00.0 $e2e2h\_xw$ 1.468184.03 $e2e2h\_xz$ 0.1791003.3845 $e3e3h\_aa$ 0.015486.3247 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.010357.73665 $e3e3h\_az$ 0.010480.395 $e3e3h\_c2e2$ 0.001488.29614 $e3e3h\_e2e2$ 0.001488.29614 $e3e3h\_e2e2$ 0.001488.29614 $e3e3h\_e3e3$ 0.4272393.5485 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.578393.977 $e3e3h\_zz$ 0.178997.779 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.0708396.8694 $nnh\_bb$ 26.7149666.85 $nnh\_cc$ 1.357567.425 $nnh\_c2a$ 0.2010156.61555 $nnh\_c3e3$ 2.9316424.115 $nnh\_gg$ 3.9722253.835 $nnh\_ss$ 0.00.0 $nnh\_xx$ 1.226838.71 $qqh\_aa$ 0.3121748.916 $qqh\_aa$ 0.3121748.916 $qqh\_aa$ 0.3121748.916 $qqh\_aa$ 0.3121748.916 $qqh\_aa$ 0.39822309.89 $qqh\_cc$ 0.038168.165 $q$	e2e2h_e3e3	0.428	2399.154
$e2e2h.ss$ $0.0$ $0.0$ $e2e2h.ww$ $1.46$ $8184.03$ $e2e2h.zz$ $0.179$ $1003.3845$ $e3e3h.aa$ $0.0154$ $86.3247$ $e3e3h.az$ $0.0103$ $57.73665$ $e3e3h.bb$ $3.89$ $21805.395$ $e3e3h.cc$ $0.196$ $1098.678$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ww$ $1.45$ $8127.975$ $e3e3h.zz$ $0.178$ $997.779$ $nnh.aa$ $0.106$ $594.183$ $nnh.ab$ $26.7$ $149666.85$ $nnh.cc$ $1.35$ $7567.425$ $nnh.e2e2$ $0.0101$ $56.61555$ $nnh.e3e3$ $2.93$ $16424.115$ $nnh.gg$ $3.97$ $22253.835$ $nnh.ss$ $0.0$ $0.0$ $nnh.mw$ $9.95$ $55774.725$ $nnh.ss$ $0.0$ $0.0$ $nnh.da$ $0.312$ $1748.916$ $qqh.aa$ $0.312$ $1748.916$ $qqh.aa$ $0.312$ $1748.916$ $qqh.e2e2$ $0.0^8$ $168.165$ $qqh.e3a$ $8.65$ $48487.575$ $qqh.gg$ $11.7$ $65584.35$ $qqh.ss$ $0.0$ $0.0$ $qqh.ss$ $0.0$ $0.0$	e2e2h_gg	0.58	3251.19
$e2e2h\_xx$ 1.468184.03 $e2e2h\_zz$ 0.1791003.3845 $e3e3h\_aa$ 0.015486.3247 $e3e3h\_az$ 0.010357.73665 $e3e3h\_bb$ 3.8921805.395 $e3e3h\_cc$ 0.1961098.678 $e3e3h\_c2e2$ 0.001488.29614 $e3e3h\_e2e2$ 0.001488.29614 $e3e3h\_e3e3$ 0.4272393.5485 $e3e3h\_e3e3$ 0.4272393.5485 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_gg$ 0.5783239.979 $e3e3h\_xz$ 0.178997.779 $nh\_aa$ 0.106594.183 $nnh\_aa$ 0.106594.183 $nnh\_aa$ 0.0708396.8694 $nnh\_bb$ 26.7149666.85 $nnh\_cc$ 1.357567.425 $nnh\_e2e2$ 0.010156.61555 $nnh\_gg$ 3.9722253.835 $nnh\_gg$ 3.9722253.835 $nnh\_ss$ 0.00.0 $nnh\_ww$ 9.9555774.725 $nnh\_xz$ 1.226838.71 $qqh\_aa$ 0.3121748.916 $qqh\_aa$ 0.2091171.5495 $qqh\_bb$ 78.9442273.95 $qqh\_c2e2$ 0.03168.165 $qqh\_e3a$ 8.6548487.575 $qqh\_gg$ 11.765584.35 $qqh\_ss$ 0.00.0 $qqh\_ss$ 0.00.0 $qqh\_ss$ 0.00.0 $qqh\_ss$ 0.00.0	e2e2h_ss	0.0	0.0
e2e2h.zz0.1791003.3845 $e3e3h.aa$ 0.0154 $86.3247$ $e3e3h.az$ 0.0103 $57.73665$ $e3e3h.bb$ $3.89$ 21805.395 $e3e3h.cc$ 0.1961098.678 $e3e3h.e2e2$ 0.00148 $8.29614$ $e3e3h.e3e3$ 0.4272393.5485 $e3e3h.e3e3$ 0.4272393.5485 $e3e3h.e3e3$ 0.4272393.5485 $e3e3h.e3e3$ 0.4272393.5485 $e3e3h.gg$ 0.5783239.979 $e3e3h.ss$ 0.00.0 $e3e3h.xz$ 0.178997.779 $nh.aa$ 0.106594.183 $nnh.aa$ 0.106594.183 $nnh.aa$ 0.0708396.8694 $nnh.bb$ 26.7149666.85 $nnh.cc$ 1.357567.425 $nnh.e2e2$ 0.010156.61555 $nnh.e3e3$ 2.9316424.115 $nnh.gg$ 3.9722253.835 $nnh.ss$ 0.00.0 $nnh.mw$ 9.9555774.725 $nnh.zz$ 1.226838.71 $qqh.aa$ 0.3121748.916 $qqh.ab$ 78.9442273.95 $qqh.ab$ 78.9442273.95 $qqh.cc$ 3.9822309.89 $qqh.cc$ 3.9822309.89 $qqh.e2e2$ 0.03168.165 $qqh.e3e3$ 8.6548487.575 $qqh.ss$ 0.00.0 $qqh.ss$ 0.00.0 $qqh.ss$ 0.00.0 $qqh.ss$ 0.00.0 $qqh.ss$ 0.0<	e2e2h_ww	1.46	8184.03
e $3e3h.aa$ 0.015486.3247e $3e3h.az$ 0.010357.73665e $3e3h.bb$ 3.8921805.395e $3e3h.cc$ 0.1961098.678e $3e3h.e2e2$ 0.001488.29614e $3e3h.e3e3$ 0.4272393.5485e $3e3h.e3e3$ 0.4272393.5485e $3e3h.e3e3$ 0.4272393.5485e $3e3h.e3e3$ 0.4272393.5485e $3e3h.e3e3$ 0.4272393.5485e $3e3h.e3e3$ 0.00.0e $3e3h.ss$ 0.00.0e $3e3h.ss$ 0.00.0e $3e3h.xz$ 0.178997.779nnh.aa0.106594.183nnh.az0.0708396.8694nnh.bb26.7149666.85nnh.cc1.357567.425nnh.e2e20.010156.61555nnh.e3e32.9316424.115nnh.gg3.9722253.835nnh.ss0.00.0nnh.ss0.00.0nnh.ww9.9555774.725nnh.zz1.226838.71qqh.aa0.3121748.916qqh.aa0.3121748.916qqh.aa0.2091171.5495qqh.bb78.9442273.95qqh.cc3.9822309.89qqh.e2e20.038168.165qqh.e3e38.6548487.575qqh.gg11.765584.35qqh.ss0.00.0qqh.ss0.00.0qqh.zz3.6120235.855	e2e2h_zz	0.179	1003.3845
$e3e3h\_az$ $0.0103$ $57.73665$ $e3e3h\_bb$ $3.89$ $21805.395$ $e3e3h\_cc$ $0.196$ $1098.678$ $e3e3h\_e2e2$ $0.00148$ $8.29614$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_as$ $0.0$ $0.0$ $e3e3h\_xs$ $0.0$ $0.0$ $e3e3h\_xz$ $0.178$ $997.779$ $nh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.0708$ $396.8694$ $nnh\_bb$ $26.7$ $149666.85$ $nnh\_cc$ $1.35$ $7567.425$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_bb$ $78.9$ $42273.95$ $qqh\_cc$ $3.98$ $22309.89$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$	e3e3h_aa	0.0154	86.3247
$e3e3h.bb$ $3.89$ $21805.395$ $e3e3h.cc$ $0.196$ $1098.678$ $e3e3h.e2e2$ $0.00148$ $8.29614$ $e3e3h.e3e3$ $0.427$ $2393.5485$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.gg$ $0.578$ $3239.979$ $e3e3h.ss$ $0.0$ $0.0$ $e3e3h.ww$ $1.45$ $8127.975$ $e3e3h.xz$ $0.178$ $997.779$ $nh.aa$ $0.106$ $594.183$ $nh.az$ $0.0708$ $396.8694$ $nh.bb$ $26.7$ $149666.85$ $nh.cc$ $1.35$ $7567.425$ $nh.e2e2$ $0.0101$ $56.61555$ $nh.e3e3$ $2.93$ $16424.115$ $nh.gg$ $3.97$ $22253.835$ $nh.ss$ $0.0$ $0.0$ $nnh.mw$ $9.95$ $55774.725$ $nh.xz$ $1.22$ $6838.71$ $qqh.aa$ $0.312$ $1748.916$ $qqh.ab$ $78.9$ $442273.95$ $qqh.bb$ $78.9$ $42273.95$ $qqh.cc$ $3.98$ $22309.89$ $qqh.e2e2$ $0.03^8$ $168.165$ $qqh.gg$ $11.7$ $65584.35$ $qqh.gg$ $11.7$ $65584.35$ $qqh.ss$ $0.0$ $0.0$ $qqh.gg$ $11.7$ $65584.35$ $qqh.gg$ $10.7$ $qqh.gg$ $11.7$ $65584.35$ $qqh.gg$ $10.7$ $qdp.gg$ $10.7$ $qdp.gg$ $10.7$ $qdp.gg$ $10.7$ $qdp.gg$ $10.7$ $qdp.gg$ $0.0$ </td <td>e3e3h_az</td> <td>0.0103</td> <td>57.73665</td>	e3e3h_az	0.0103	57.73665
$e3e3h\_cc$ $0.196$ $1098.678$ $e3e3h\_e2e2$ $0.00148$ $8.29614$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_xs$ $0.0$ $0.0$ $e3e3h\_xs$ $0.0$ $0.0$ $e3e3h\_xz$ $0.178$ $997.779$ $nh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.0708$ $396.8694$ $nnh\_bb$ $26.7$ $149666.85$ $nnh\_cc$ $1.35$ $7567.425$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_xs$ $0.0$ $0.0$ $nnh\_xz$ $1.22$ $6838.71$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_bb$ $78.9$ $42273.95$ $qqh\_cc$ $3.98$ $22309.89$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_xx$ $3.61$ $20235.855$	e3e3h_bb	3.89	21805.395
$e3e3h\_e2e2$ $0.00148$ $8.29614$ $e3e3h\_e3e3$ $0.427$ $2393.5485$ $e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_ss$ $0.0$ $0.0$ $e3e3h\_ss$ $0.0$ $0.0$ $e3e3h\_xw$ $1.45$ $8127.975$ $e3e3h\_zz$ $0.178$ $997.779$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.0708$ $396.8694$ $nnh\_bb$ $26.7$ $149666.85$ $nnh\_cc$ $1.35$ $7567.425$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_xw$ $9.95$ $55774.725$ $nnh\_xz$ $1.22$ $6838.71$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_bb$ $78.9$ $442273.95$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$	e3e3h_cc	0.196	1098.678
$e3e3h_e3e3$ $0.427$ $2393.5485$ $e3e3h_gg$ $0.578$ $3239.979$ $e3e3h_ss$ $0.0$ $0.0$ $e3e3h_ww$ $1.45$ $8127.975$ $e3e3h_zz$ $0.178$ $997.779$ $nnh_aa$ $0.106$ $594.183$ $nnh_az$ $0.0708$ $396.8694$ $nnh_az$ $0.0708$ $396.8694$ $nnh_cc$ $1.35$ $7567.425$ $nnh_cc$ $1.35$ $7567.425$ $nnh_e2e2$ $0.0101$ $56.61555$ $nnh_e3e3$ $2.93$ $16424.115$ $nnh_gg$ $3.97$ $22253.835$ $nnh_ss$ $0.0$ $0.0$ $nnh_ss$ $0.0$ $0.0$ $nnh_ss$ $0.0$ $0.0$ $nnh_zz$ $1.22$ $6838.71$ $qqh_aa$ $0.312$ $1748.916$ $qqh_aa$ $0.312$ $1748.916$ $qqh_e2e2$ $0.03^8$ $168.165$ $qqh_e2e2$ $0.03^8$ $168.165$ $qqh_e3e3$ $8.65$ $48487.575$ $qqh_ss$ $0.0$ $0.0$ $qqh_ss$ $0.0$ $0.0$ $qqh_ss$ $0.0$ $0.0$	e3e3h_e2e2	0.00148	8.29614
$e3e3h\_gg$ $0.578$ $3239.979$ $e3e3h\_ss$ $0.0$ $0.0$ $e3e3h\_ww$ $1.45$ $8127.975$ $e3e3h\_zz$ $0.178$ $997.779$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.0708$ $396.8694$ $nnh\_az$ $0.0708$ $396.8694$ $nnh\_e2$ $0.0101$ $56.61555$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_ac$ $0.08^8$ $22309.89$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$	e3e3h_e3e3	0.427	2393.5485
$e3e3h\_ss$ $0.0$ $0.0$ $e3e3h\_ww$ $1.45$ $8127.975$ $e3e3h\_zz$ $0.178$ $997.779$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_aa$ $0.0708$ $396.8694$ $nnh\_az$ $0.0708$ $396.8694$ $nnh\_bb$ $26.7$ $149666.85$ $nnh\_cc$ $1.35$ $7567.425$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_xw$ $9.95$ $55774.725$ $nnh\_xz$ $1.22$ $6838.71$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_bb$ $78.9$ $442273.95$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_xz$ $3.61$ $20235.855$	e3e3h_gg	0.578	3239.979
$e3e3h\_ww$ $1.45$ $8127.975$ $e3e3h\_zz$ $0.178$ $997.779$ $nnh\_aa$ $0.106$ $594.183$ $nnh\_az$ $0.0708$ $396.8694$ $nnh\_bb$ $26.7$ $149666.85$ $nnh\_cc$ $1.35$ $7567.425$ $nnh\_e2e2$ $0.0101$ $56.61555$ $nnh\_e3e3$ $2.93$ $16424.115$ $nnh\_gg$ $3.97$ $22253.835$ $nnh\_ss$ $0.0$ $0.0$ $nnh\_xw$ $9.95$ $55774.725$ $nnh\_xz$ $1.22$ $6838.71$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.312$ $1748.916$ $qqh\_aa$ $0.209$ $1171.5495$ $qqh\_ac$ $3.98$ $22309.89$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_xz$ $3.61$ $20235.855$	e3e3h_ss	0.0	0.0
$e3e3h_zz$ $0.178$ $997.779$ $nnh_aa$ $0.106$ $594.183$ $nnh_az$ $0.0708$ $396.8694$ $nnh_bb$ $26.7$ $149666.85$ $nnh_cc$ $1.35$ $7567.425$ $nnh_e2e2$ $0.0101$ $56.61555$ $nnh_e3e3$ $2.93$ $16424.115$ $nnh_gg$ $3.97$ $22253.835$ $nnh_ss$ $0.0$ $0.0$ $nnh_ss$ $0.0$ $0.0$ $nnh_xw$ $9.95$ $55774.725$ $nnh_zz$ $1.22$ $6838.71$ $qqh_aa$ $0.312$ $1748.916$ $qqh_az$ $0.209$ $1171.5495$ $qqh_cc$ $3.98$ $22309.89$ $qqh_e3e3$ $8.65$ $48487.575$ $qqh_gg$ $11.7$ $65584.35$ $qqh_ss$ $0.0$ $0.0$ $qqh_ss$ $0.0$ $0.0$ $qqh_ss$ $0.0$ $0.0$	e3e3h_ww	1.45	8127.975
nnh_aa $0.106$ $594.183$ nnh_az $0.0708$ $396.8694$ nnh_bb $26.7$ $149666.85$ nnh_cc $1.35$ $7567.425$ nnh_c2e2 $0.0101$ $56.61555$ nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_xw $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	e3e3h_zz	0.178	997.779
nnh_az $0.0708$ $396.8694$ nnh_bb $26.7$ $149666.85$ nnh_cc $1.35$ $7567.425$ nnh_c2e2 $0.0101$ $56.61555$ nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_aa	0.106	594.183
nnh_bb $26.7$ $149666.85$ nnh_cc $1.35$ $7567.425$ nnh_e2e2 $0.0101$ $56.61555$ nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_az	0.0708	396.8694
nnh_cc $1.35$ $7567.425$ nnh_e2e2 $0.0101$ $56.61555$ nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_e2e2 $0.03^8$ $168.165$ qqh_e3e3 $8.65$ $48487.575$ qqh_ss $0.0$ $0.0$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_bb	26.7	149666.85
nnh_e2e2 $0.0101$ $56.61555$ nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_e2e2 $0.03^8$ $168.165$ qqh_e3e3 $8.65$ $48487.575$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_cc	1.35	7567.425
nnh_e3e3 $2.93$ $16424.115$ nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_e3e3 $8.65$ $48487.575$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_e2e2	0.0101	56.61555
nnh_gg $3.97$ $22253.835$ nnh_ss $0.0$ $0.0$ nnh_ww $9.95$ $55774.725$ nnh_zz $1.22$ $6838.71$ qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_zz $3.61$ $20235.855$	nnh_e3e3	2.93	16424.115
nnh_ss         0.0         0.0           nnh_ww         9.95         55774.725           nnh_zz         1.22         6838.71           qqh_aa         0.312         1748.916           qqh_az         0.209         1171.5495           qqh_cc         3.98         22309.89           qqh_e2e2         0.03 <sup>8</sup> 168.165           qqh_e3e3         8.65         48487.575           qqh_gg         11.7         65584.35           qqh_ss         0.0         0.0           qqh_zz         3.61         20235.855	nnh_gg	3.97	22253.835
nnh_ww9.9555774.725nnh_zz1.226838.71qqh_aa0.3121748.916qqh_az0.2091171.5495qqh_bb78.9442273.95qqh_cc3.9822309.89qqh_e2e20.03 <sup>8</sup> 168.165qqh_e3e38.6548487.575qqh_gg11.765584.35qqh_ss0.00.0qqh_ww29.4164801.7qqh_zz3.6120235.855	nnh_ss	0.0	0.0
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	nnh_ww	9.95	55774.725
qqh_aa $0.312$ $1748.916$ qqh_az $0.209$ $1171.5495$ qqh_bb $78.9$ $442273.95$ qqh_cc $3.98$ $22309.89$ qqh_e2e2 $0.03^8$ $168.165$ qqh_e3e3 $8.65$ $48487.575$ qqh_gg $11.7$ $65584.35$ qqh_ss $0.0$ $0.0$ qqh_ww $29.4$ $164801.7$ qqh_zz $3.61$ $20235.855$	nnh_zz	1.22	6838.71
qqh_az       0.209       1171.5495         qqh_bb       78.9       442273.95         qqh_cc       3.98       22309.89         qqh_e2e2       0.03 <sup>8</sup> 168.165         qqh_e3e3       8.65       48487.575         qqh_gg       11.7       65584.35         qqh_ss       0.0       0.0         qqh_zz       3.61       20235.855	qqh_aa	0.312	1748.916
$qqh\_bb$ $78.9$ $442273.95$ $qqh\_cc$ $3.98$ $22309.89$ $qqh\_e2e2$ $0.03^8$ $168.165$ $qqh\_e3e3$ $8.65$ $48487.575$ $qqh\_gg$ $11.7$ $65584.35$ $qqh\_ss$ $0.0$ $0.0$ $qqh\_ww$ $29.4$ $164801.7$ $qqh\_zz$ $3.61$ $20235.855$	qqh_az	0.209	1171.5495
qqh_cc       3.98       22309.89         qqh_e2e2       0.03 <sup>8</sup> 168.165         qqh_e3e3       8.65       48487.575         qqh_gg       11.7       65584.35         qqh_ss       0.0       0.0         qqh_ww       29.4       164801.7         qqh_zz       3.61       20235.855	qqh_bb	78.9	442273.95
qqh_e2e2       0.03 <sup>8</sup> 168.165         qqh_e3e3       8.65       48487.575         qqh_gg       11.7       65584.35         qqh_ss       0.0       0.0         qqh_ww       29.4       164801.7         qqh_zz       3.61       20235.855	qqh_cc	3.98	22309.89
qqh_e3e3       8.65       48487.575         qqh_gg       11.7       65584.35         qqh_ss       0.0       0.0         qqh_ww       29.4       164801.7         qqh_zz       3.61       20235.855	qqh_e2e2	0.038	168.165
qqh_gg       11.7       65584.35         qqh_ss       0.0       0.0         qqh_ww       29.4       164801.7         qqh_zz       3.61       20235.855	qqh_e3e3	8.65	48487.575
qqh_ss     0.0     0.0       qqh_ww     29.4     164801.7       qqh_zz     3.61     20235.855	aah_gg	11.7	65584.35
qqh_ww 29.4 164801.7 qqh_zz 3.61 20235.855	agh_ss	0.0	0.0
qqh_zz 3.61 20235.855	qah_ww	29.4	164801.7
	qqh_zz	3.61	20235.855

Table 2: ZH sample list

### **122 2.2 Two fermions background Samples**

Process	Cross section	Events expected
qq	54106.86	303296003.73
e2e2	5332.71	29892506.46
e3e3	4752.89	26642325.45
e1e1	24770.9	138853279.95
n1n1	45390.79	254438073.9
n2n2	4416.3	24755569.65
n3n3	4410.26	24721712.43

Table 3: General information about two fermions background samples

### **2.3** Four fermions background Samples

Process	Cross section	Events expected
zz_h0utut	85.68	480279.24
zz_h0dtdt	233.46	1308660.03
zz_h0uu_notd	98.56	552478.08
zz_h0cc_nots	98.97	554776.89
zz_sl0nu_up	84.38	472992.09
zz_sl0nu_down	139.71	783144.96
zz_sl0mu_up	87.39	489865.2
zz_sl0mu_down	136.14	763132.77
zz_sl0tau_up	41.56	232964.58
zz_sl0tau_down	67.31	377306.76
zz_104tau	4.61	25841.91
zz_104mu	15.56	87221.58
zz_10taumu	18.56	104038.08
zz_10mumu	19.38	108634.59
zz_10tautau	9.61	53869.41
ww_h0cuxx	3478.89	19500918.45
ww_h0uubd	0.05	280.83
ww_h0uusd	170.45	955458.03
ww_h0ccbs	5.89	33016.95
ww_h0ccds	170.18	953943.99
ww_s10muq	2423.43	13584537.42
ww_sl0tauq	2423.56	13585265.58
ww_1011	403.66	2262716.13
zzorww_h0udud	1610.32	9026648.76
zzorww_h0cscs	1607.55	9011122.08
zzorww_10mumu	221.1	1239376.05
zzorww_10tautau	211.18	1183769.49
sze_10tau	147.28	825578.04
sze_10mu	845.81	4741188.51
sze_10nunu	28.94	162223.17
sze_sl0uu	190.21	1066222.71
sze_sl0dd	125.83	705340.62
sznu_10mumu	43.42	243390.81
sznu_10tautau	14.57	81672.69
sznu_sl0nu_up	55.59	311610.3
sznu_sl0nu_down	90.03	504663.72
sw_10mu	436.7	2447921.85
sw_10tau	435.93	2443606.17
sw_sl0qq	2612.62	14645041.41
szeorsw_101	249.48	1398460.14

Table 4: General information about four fermions background samples

#### **Analysis Procedure** 3 124

132

We give here a brief explanation about the analysis framework which is common to all of indivisual 125 channels. The Marlin framework is used for this flow. 126

The analysis starts from the reconstructed objects as inputs. The lepton isolation processor, the jet clus-127 tering processor are applied on the Arbor PFO to separate leptons from the rest. The remain objects are 128 going to be clustered into number of jets by the the jet clustering processor, where we can designate 129 the jet algorithm to be used, the number of (exclusive) jets and so on. Classified objects are feed into a 130 processor which we call it internally as "Higgs2zz" processor and pre selection on events are performed. 131 Fig. 1 is the skematic of the analysis flow chart, and further details are given in the following items.



## Analysis flow chart

Figure 1: Analysis Flow Chart

#### Lepton Isolation 133

The leptons, here they are electrons and muons, like the decay particles of the initial Z boson, 134 should not be merged into jets, and the task is done by this lepton isoloation processor. The 135 isolated status is judged from several condistions, such as particles having "cone energy" which is 136 lower than certain thredhold, as well as requiring its PID as that of electrons or muons. The input 137 collection to the processor is the Arbor PFO, and it has two output collections, one includes only 138 isolated leptons, the other includes the rest. 139

#### 140 Jet Clustering

FastJet processor has been chosen for the jet clustering process. We have used so-called "eekt" algorithm. The input collection is the one which does not include isolated leptons, and that is clustered into two jets exclusively, by setting the number of jets option as two. The output collection of this processor has information of these two jets.

#### 145 Event Preselection

The "Higgs2zz" processor has role of the event preselection. The input collections consists of output of the lepton isolation processor for the isolated leptons, output of the fastjet processor for the jets, the Arbor PFO collection and the MCParticle collection for MC truth information. If event contains one positive charged lepton and one minus charged lepton in the isolated lepton collection, and the two jets from the fastjet processor, this event is saved. Several meaningful information, such as di lepton mass and momentum, are obtained at this stage and as well.

Typical distribusions after this pre selection process on  $\mu\mu$ HZZ signal sample are shown in Fig. 2-3. Corresponding description about the histograms should be given briefly here.



Figure 2: Distributions of the invariant mass and the recoil mass of di-muons. The figures shall be updated. .



Figure 3: Visible (but except the di-muons) mass distribution. Or, di-jet invariant mass distribution.. The figures shall be updated. .

### <sup>154</sup> **4** Event Selection of $Z(\rightarrow \mu\mu)H(ZZ^*\rightarrow \nu\nu qq)$

### 155 **4.1** $\mathbf{Z}(\rightarrow \mu^+\mu^-), \mathbf{H}(\mathbf{Z}\rightarrow\nu\bar{\nu}, \mathbf{Z}^*\rightarrow q\bar{q})$

#### 156 4.1.1 Event selection (Cut-based only)

					c
Cut	Signal	ZH background	2f background	4f background	$\frac{S}{\sqrt{S+B}}$
Expected	1000	1140511	801811977	107203890	
Pre – selection	616	30494	480828	515448	
Signal or not	211	30282	480828	515448	
$M_{missing} > M_{dijet}$	107	1608	115062	28809	0.283
N(pfo)	104	908	33480	14159	0.4722
$M_{dimuon}$	92	296	24151	1625	0.5714
$M_{dijet}$	87	280	851	819	1.9395
$M_{missing}$	71	124	97	101	3.6196
$cos \theta_{visible}$	68	118	22	39	4.349
$Angle_{\mu j}$	62	95	14	20	4.4919
$M^{rec}_{dimuon}$	61	79	14	8	4.7795
$M_{dijet}^{rec}$	59	69	0	4	5.1374
not qqHZZ	59	69	0	4	5.1374
not vvHZZ	50	36	0	4	5.2503

Table 5: Cut flow table for  $\mu\mu\nu\nu qq$  channel

Table 6: Remained backgrounds (more than 1 event) after all of cuts applied.

name	scale	final
e2e2h_e3e3	0.023968	2
e2e2h_ww	0.08176	22
nnh_zz	0.06832	10
zz_sl0mu_down	1.08025726079	1
zz_sl0tau_up	1.10880522921	1
zz_10taumu	1.0404004004	2

<sup>157</sup> The event selection cuts are listed below in sequence.

•  $M_{miss} > M_{dijets}$ : the missing mass is greater than the dijet invariant mass.

•  $20 < N_{pfo} < 90$ : Number of Prticle Flow Objects should be in this range.

•  $80GeV < M_{\mu^+\mu^-} < 100GeV$ : the invariant mass of the dimuon should be in this range.



Figure 4: Missing mass vs dijet invariant mass.



Figure 5: Number of PFOs.



Figure 6: Invariant mass of di-muons.



Figure 7: Invariant mass of di-jets.

•  $15GeV < M_{dijet} < 60GeV$ : the invariant mass of dijet should be in this range.



Figure 8: Recoil mass of visible particles.

•  $75GeV < M_{visible}^{Recoil} < 105GeV$ : the recoil mass of all visible particles should be in this range. 162  $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range 163 •  $60 < Min angle < 170^{\circ}$ : Minimum angle between the two Z(Z\*) reconstructed by leptons and jets 164 should be within this range. 165 •  $110GeV < M_{Recoil}^{dimuon} < 140GeV$ : the recoil mass of the dimuon should be in this range. 166 •  $185GeV < M_{Recoil}^{dijet} < 220GeV$ : the recoil mass of the dijet should be in this range. 167 Two additional cuts: 168 •  $M_{dijet}^{rec} < 122 GeV \text{ or } M_{dijet}^{rec} > 128 GeV$ : To avoid the overlap events with qqHZZ signals. 169 •  $M_{visible} < 122 GeV \text{ or } M_{visible} > 128 GeV$ : To remove the overlap events with vvHZZ signals. 170



Figure 9: All visible particle  $\cos \theta$ 



Figure 10: Minimum angle between the two  $Z(Z^*)$  reconstructed by leptons and jets.



Figure 11: Recoil mass of di-muons.



Figure 12: Recoil mass of di-jets.



Figure 13: Distribution of the recoil mass of dimuon, after all of cuts applied.

#### 171 **4.2** $\mathbf{Z}(\rightarrow \mu^+\mu^-), \mathbf{H}(\mathbf{Z}\rightarrow q\bar{q}, \mathbf{Z}^*\rightarrow\nu\bar{\nu})$

#### 172 4.2.1 Event selection (Cut-based only)

- $M_{miss} > M_{dijets}$ : the missing mass is greater than the dijet invariant mass.
- $30 < N_{pfo} < 100$ : Number of Prticle Flow Objects should be in this range.
- $80GeV < M_{\mu^+\mu^-} < 100GeV$ : the invariant mass of the dimuon should be in this range.
- $60GeV < M_{dijet} < 105GeV$ : the invariant mass of dijet should be in this range.
- $10GeV < M_{visible}^{Recoil} < 55GeV$ : the recoil mass of all visible particles should be in this range.
- $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range

Cut	Signal	ZH background	2f background	4f background	S
Expected	1000	1140511	801811977	107203890	$\sqrt{S+B}$
Pre – selection	616	30494	480828	515448	
Signal or not	211	30282	480828	515448	
$M_{missing} < M_{dijet}$	103	28674	365766	486638	0.1102
N(pfo)	100	21686	12184	332162	0.1657
M <sub>dimuon</sub>	89	16833	9085	207927	0.186
$M_{dijet}$	82	2768	52	173775	0.1974
$M_{missing}$	71	1679	14	13434	0.5804
$*\cos\theta$	71	1679	14	13434	0.5804
$cos \theta_{visible}$	67	1535	0	8545	0.6749
$Angle_{\mu j}$	57	1109	0	2197	0.995
M <sup>rec</sup>	56	1048	0	941	1.2488
$*M_{dijet}^{rec}$	56	1048	0	941	1.2488
$M_{visible}$	54	930	0	790	1.2823
$*P_{visible}$	54	930	0	790	1.2823
$*P_{T_{visible}}$	54	930	0	790	1.2823
$*E_{leading jet}$	54	930	0	790	1.2823
$*P_{T_{leading} iet}$	54	930	0	790	1.2823
$*E_{sub-leading jet}$	54	930	0	790	1.2823
$*P_{T_{sub-leading jet}}$	54	930	0	790	1.2823
not qqHZZ	46	738	0	644	1.2343
not vvHZZ	46	738	0	644	1.2343

Table 7: Cut flow table for  $\mu\mu qq\nu\nu$  channel

Table 8: Remained backgrounds (more than 1 event) after all of cuts applied.

name	scale	final
e2e2h_bb	0.21896	405
e2e2h_cc	0.011032	5
e2e2h_e3e3	0.023968	5
e2e2h_gg	0.0326888819557	1
e2e2h_ww	0.08176	282
e2e2h_zz	0.010024	6
e3e3h_zz	0.009968099681	1
qqh_e3e3	0.4844	7
qqh_ww	1.6464	1
qqh_zz	0.20216	21
zz_sl0mu_up	1.09032214858	159
zz_sl0mu_down	1.08025726079	473
zz_sl0tau_down	1.10887174477	5
ww_sl0muq	1.2235862395	6
zz_sl0tau_down ww_sl0muq	1.10887174477 1.2235862395	



Figure 14: Missing mass vs dijet invariant mass.



Figure 15: Number of PFOs.



Figure 16: Invariant mass of di-muons.



Figure 17: Invariant mass of di-jets.



Figure 18: Recoil mass of visible particles.



Figure 19: All visible particle  $\cos \theta$ 



Figure 20: Minimum angle between the two  $Z(Z^*)$  reconstructed by leptons and jets.



Figure 21: Recoil mass of di-muons.

- $120 < Min \ angle < 170^{\circ}$ : Minimum angle between the two Z(Z\*) reconstructed by leptons and jets should be within this range.
- $110GeV < M_{Recoil}^{dimuon} < 140GeV$ : the recoil mass of the dimuon should be in this range.



Figure 22: Visible mass of all particles.

- $175GeV < M_{visible} < 215GeV$ : the visible mass of all particles should be in this range.
- 184 Two additional cuts:
- $M_{dijet}^{rec} < 122 GeV \text{ or } M_{dijet}^{rec} > 128 GeV$ : To avoid the overlap events with qqHZZ signals.
- $M_{visible} < 122 GeV \text{ or } M_{visible} > 128 GeV$ : To remove the overlap events with vvHZZ signals.



Figure 23: Distribution of the recoil mass of dimuon, after all of cuts applied.

### <sup>187</sup> 5 Event Selection of $Z(\rightarrow \nu\nu)H(ZZ^*\rightarrow \mu\mu qq)$

### 188 **5.1** $\mathbf{Z}(\rightarrow \nu \bar{\nu}), \mathbf{H}(\mathbf{Z}\mathbf{Z}^* \rightarrow \mu^+ \mu^- \rightarrow q\bar{q})$

#### 189 5.1.1 Event selection (Cut-based only)

=

Cut	Signal	ZH background	2f background	4f background	$\frac{S}{\sqrt{S+B}}$
Expected	6844	1140511	801811977	107203890	
Pre – selection	238	30494	480828	515424	
S ignal or not	226	30268	480828	515424	
$M_{dimuon} > M_{dijet}$	125	2832	421952	156993	0.1642
N(pfo)	117	1259	60398	68100	0.325
$M_{missing}$	102	147	2152	791	1.8168
$M_{dimuon}$	95	136	1762	258	2.007
$M_{dijet}$	94	131	258	204	3.5888
$*cos \theta$	94	131	258	204	3.5888
$cos \theta_{visible}$	89	125	37	57	5.0842
$Angle_{\mu j}$	83	72	0	16	6.3751
$*M_{dimuon}^{rec}$	83	72	0	16	6.3751
$*M_{dijet}^{rec}$	83	72	0	16	6.3751
$M_{visible}$	83	56	0	11	6.7871
$*P_{visible}$	83	56	0	11	6.7871
$*P_{T_{visible}}$	83	56	0	11	6.7871
$*E_{leading jet}$	83	56	0	11	6.7871
$*P_{T_{leading jet}}$	83	56	0	11	6.7871
$*E_{sub-leading jet}$	83	56	0	11	6.7871
$*P_{T_{sub-leading jet}}$	83	56	0	11	6.7871
not $\mu^+\mu^-HZZ$	72	17	0	9	7.2837
not qqHZZ	72	17	0	9	7.2837

Table 9: Cut flow table for  $vv\mu\mu qq$  channel

<sup>190</sup> The event selection cuts are listed below in sequence.

•  $M_{dimuon} > M_{dijets}$ : the dimuon invariant mass is greater than the dijet invariant mass.

•  $20 < N_{pfo} < 60$ : Number of Prticle Flow Objects should be in this range.

•  $75GeV < M_{visible}^{Recoil} < 110GeV$ : the recoil mass of all visible particles should be in this range.

•  $60GeV < M_{\mu^+\mu^-} < 100GeV$ : the invariant mass of the dimuon should be in this range.

name	scale	final
e2e2h_ww	0.08176	4
e2e2h_zz	0.010024	9
e3e3h_ww	0.0812	2
zz_sl0tau_up	1.10880522921	1
zz_10taumu	1.0404004004	1
ww_sl0muq	1.10890944134	3
ww_sl0tauq	1.10899434445	1
zzorww_10mumu	1.10891486372	1
sze_10mu	1.10916641266	1

Table 10: Remained backgrounds (more than 1 event) after all of cuts applied.



Figure 24: dimuon invariant mass vs dijet invariant mass.



Figure 25: Number of PFOs.



Figure 26: Recoil mass of visible particles.



Figure 27: Invariant mass of di-muons.



Figure 28: Invariant mass of di-jets.



Figure 29: All visible particle  $\cos \theta$ 

195	• $10GeV < M_{dijet} < 55GeV$ : the invariant mass of dijet should be in this range.
196	• $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range
197 198	• <i>Min angle</i> < 135°: Minimum angle between the two Z(Z*) reconstructed by leptons and jets should be within this range .
199	• $110GeV < M_{visible} < 140GeV$ : the invariant mass of all visible particles should be in this range.
200	Two additional cuts:
201	• $M_{dimuon}^{rec} < 122 GeV \text{ or } M_{dimuon}^{rec} > 128 GeV$ : To avoid the overlap events with $\mu\mu$ HZZ signals.
202	• $M_{dijet}^{rec} < 122 GeV \text{ or } M_{dijet}^{rec} > 128 GeV$ : To remove the overlap events with $qq$ HZZ signals.



Figure 30: Minimum angle between the two  $Z(Z^*)$  reconstructed by leptons and jets.



Figure 31: Invariant mass of all visible particles.



Figure 32: Distribution of the visible mass of all particles, after all of cuts applied.

### 203 5.2 $\mathbf{Z}(\rightarrow \nu \bar{\nu}), \mathbf{H}(\mathbf{Z} \rightarrow q\bar{q}, \mathbf{Z}^* \rightarrow \mu^+ \mu^-)$

#### 204 5.2.1 Event selection (Cut-based only)

- $M_{dimuon} < M_{dijets}$ : the dijet invariant mass is greater than the dimuon invariant mass.
- $30 < N_{pfo} < 100$ : Number of Prticle Flow Objects should be in this range.
- $75GeV < M_{visible}^{Recoil} < 110GeV$ : the recoil mass of all visible particles should be in this range.
- $10GeV < M_{\mu^+\mu^-} < 60GeV$ : the invariant mass of the dimuon should be in this range.
- $60GeV < M_{dijet} < 100GeV$ : the invariant mass of dijet should be in this range.
- $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range

Cut	Signal	7H background	2f background	Af background	S
		211 background	21 background	107202000	$\sqrt{S+B}$
Expected	6844	1140511	801811977	107203890	
Pre – selection	238	30494	480828	515424	
S ignal or not	226	30268	480828	515424	
$M_{dimuon} < M_{dijet}$	101	27436	58876	358431	0.1521
N(pfo)	97	20843	364	231698	0.1939
$M_{missing}$	79	769	37	2083	1.4508
$M_{dimuon}$	78	707	7	1732	1.5596
$M_{dijet}$	68	576	0	830	1.7719
$*cos \theta$	68	576	0	830	1.7719
$cos \theta_{visible}$	64	552	0	452	1.9743
$Angle_{\mu j}$	59	239	0	70	3.1041
$M^{rec}_{dimuon}$	58	214	0	65	3.184
$*M_{dijet}^{rec}$	58	214	0	65	3.184
$M_{visible}$	57	175	0	54	3.4122
$*P_{visible}$	57	175	0	54	3.4122
$*P_{T_{visible}}$	57	175	0	54	3.4122
$*E_{leading jet}$	57	175	0	54	3.4122
$*P_{T_{leading jet}}$	57	175	0	54	3.4122
$*E_{sub-leading jet}$	57	175	0	54	3.4122
$*P_{T_{sub-leading jet}}$	57	175	0	54	3.4122
not $\mu^+\mu^-HZZ$	57	175	0	54	3.4122
not qqHZZ	50	130	0	43	3.3773

Table 11: Cut flow table for  $vvqq\mu\mu$  channel

Table 12: Remained backgrounds (more than 1 event) after all of cuts applied.

name	scale	final
e2e2h_bb	0.21896	8
e2e2h_ww	0.08176	7
e3e3h_bb	0.21784	2
e3e3h_ww	0.0812	9
qqh_e3e3	0.4844	34
qqh_ww	1.6464	51
qqh_zz	0.20216	14
zz_sl0mu_down	1.08025726079	2
zz_sl0tau_up	1.10880522921	8
zz_sl0tau_down	1.10887174477	19
ww_sl0muq	1.10890944134	2
ww_sl0tauq	1.10899434445	3
sze_10mu	1.10916641266	6



Figure 33: dimuon invariant mass vs dijet invariant mass.



Figure 34: Number of PFOs.



Figure 35: Recoil mass of visible particles.



Figure 36: Invariant mass of di-muons.



Figure 37: Invariant mass of di-jets.



Figure 38: All visible particle  $\cos \theta$ 



Figure 39: Minimum angle between the two  $Z(Z^*)$  reconstructed by leptons and jets.



Figure 40: Recoil mass of dimuons.

- *Min angle* <  $130^{\circ}$ : Minimum angle between the two Z(Z\*) reconstructed by leptons and jets should be within this range.
- $165GeV < M_{dimuon}^{rec} < 215GeV$ : the recoil mass of dimuons should be in this range.



Figure 41: Invariant mass of all visible particles.

- $110GeV < M_{visible} < 140GeV$ : the invariant mass of all visible particles should be in this range.
- Two additional cuts:
- $M_{dimuon}^{rec} < 122 GeV \text{ or } M_{dimuon}^{rec} > 128 GeV$ : To avoid the overlap events with  $\mu\mu$ HZZ signals.
- $M_{dijet}^{rec} < 122 GeV \text{ or } M_{dijet}^{rec} > 128 GeV$ : To remove the overlap events with qqHZZ signals.



Figure 42: Distribution of the visible mass of all particles, after all of cuts applied.

# <sup>219</sup> 6 Event Selection of $Z(\rightarrow qq)H(ZZ^*\rightarrow \nu\nu\mu\mu)$

### 220 **6.1** $\mathbf{Z}(\rightarrow q\bar{q}), \mathbf{H}(\mathbf{Z}\rightarrow \nu\bar{\nu}, \mathbf{Z}^*\rightarrow \mu^+\mu^-)$

#### 221 6.1.1 Event selection (Cut-based only)

Cut	Signal	ZH background	2f background	4f background	$\frac{S}{\sqrt{S+B}}$
Expected	20254	1140511	801811977	107203890	1515
Pre – selection	826	30494	480828	515424	
S ignal or not	203	30291	480828	515424	
$M_{missing} > M_{dimuon}$	94	3179	18606	40769	0.3795
N(pfo)	84	2242	1212	12626	0.6659
$M_{dijet}$	75	1532	7	4965	0.9263
$M_{dimuon}$	68	1231	0	2803	1.0623
$M_{missing}$	57	575	0	572	1.6625
$*cos \theta$	57	575	0	572	1.6625
$cos \theta_{visible}$	55	551	0	403	1.7334
$*Angle_{\mu j}$	55	551	0	403	1.7334
$M_{dimuon}^{rec}$	53	493	0	348	1.7877
$M_{dijet}^{rec}$	51	418	0	237	1.9265
$M_{visible}$	48	374	0	209	1.9087
$*P_{visible}$	48	374	0	209	1.9087
$*P_{T_{visible}}$	48	374	0	209	1.9087
$*E_{leading jet}$	48	374	0	209	1.9087
$*P_{T_{leading jet}}$	48	374	0	209	1.9087
$*E_{sub-leading jet}$	48	374	0	209	1.9087
$*P_{T_{sub-leading jet}}$	48	374	0	209	1.9087
not $\mu^+\mu^-HZZ$	48	374	0	209	1.9087
not vvHZZ	41	326	0	190	1.764

- The event selection cuts are listed below in sequence.
- $M_{miss} > M_{dimuon}$ : the missing mass is greater than the dimuon invariant mass.
- $40 < N_{pfo} < 95$ : Number of Prticle Flow Objects should be in this range.
- $75GeV < M_{dijet} < 105GeV$ : the invariant mass of dijet should be in this range.
- $15GeV < M_{\mu^+\mu^-} < 55GeV$ : the invariant mass of the dimuon should be in this range.

name	scale	final
e2e2h_bb	0.21896	14
e2e2h_ww	0.08176	4
e3e3h_bb	0.21784	9
e3e3h_ww	0.0812	11
nnh_zz	0.06832	34
qqh_e3e3	0.4844	205
qqh_ww	1.6464	92
zz_sl0mu_up	1.09032214858	4
zz_sl0mu_down	1.08025726079	5
zz_sl0tau_up	1.10880522921	63
zz_sl0tau_down	1.10887174477	129
sze_10mu	1.10916641266	6

Table 14: Remained backgrounds (more than 1 event) after all of cuts applied.



Figure 43: Missing mass vs dimuon invariant mass.



Figure 44: Number of PFOs.



Figure 45: Invariant mass of di-jets.



Figure 46: Invariant mass of di-muons.



Figure 47: Recoil mass of visible particles.



Figure 48: All visible particle  $\cos \theta$ 

227	• $70GeV < M_{visible}^{Recoil} < 110GeV$ : the recoil mass of all visible particles should be in this range.
228	• $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range
229	• $175GeV < M_{Recoil}^{dimuon} < 215GeV$ : the recoil mass of the dimuon should be in this range.
230	• $110GeV < M_{Recoil}^{dijet} < 140GeV$ : the recoil mass of the dijet should be in this range.
231	• $115GeV < M_{visible} < 155GeV$ : the visible mass of all particles should be in this range.
232	Two additional cuts:
233	• $M_{dimuon}^{rec} < 122 GeV \text{ or } M_{dimuon}^{rec} > 128 GeV$ : To avoid the overlap events with $\mu\mu$ HZZ signals.
234	• $M_{visible} < 122 GeV \text{ or } M_{visible} > 128 GeV$ : To remove the overlap events with vvHZZ signals.



Figure 49: Recoil mass of di-muons.



Figure 50: Recoil mass of di-jets.



Figure 51: Visible mass of all particles.



Figure 52: Distribution of the recoil mass of dijet, after all of cuts applied.

### 235 **6.2** $\mathbf{Z}(\rightarrow q\bar{q}), \mathbf{H}(\mathbf{Z}\rightarrow \mu^+\mu^-, \mathbf{Z}^*\rightarrow \nu\bar{\nu})$

#### 236 6.2.1 Event selection (Cut-based only)

Cut	Signal	ZH background	2f background	4f background	$\frac{S}{\sqrt{S+B}}$
Expected	20254	1140511	801811977	107203890	1515
Pre – selection	826	30494	480828	515424	
S ignal or not	203	30291	480828	515424	
$M_{missing} < M_{dimuon}$	108	27112	462222	474655	0.1104
N(pfo)	103	19806	17185	313602	0.1741
$M_{dijet}$	97	4531	44	250527	0.1937
M <sub>dimuon</sub>	83	3468	14	174150	0.1989
$M_{missing}$	64	1961	7	11132	0.5648
$*cos \theta$	64	1961	7	11132	0.5648
$cos \theta_{visible}$	60	1796	0	6827	0.652
$Angle_{\mu j}$	53	1197	0	1264	1.0622
$M_{dimuon}^{rec}$	51	1194	0	661	1.1737
$M_{diiet}^{rec}$	48	950	0	534	1.2364
$M_{visible}$	45	749	0	464	1.2781
$*P_{visible}$	45	749	0	464	1.2781
$*P_{T_{visible}}$	45	749	0	464	1.2781
$*E_{leading jet}$	45	749	0	464	1.2781
$*P_{T_{leading}}$ jet	45	749	0	464	1.2781
$*E_{sub-leading jet}$	45	749	0	464	1.2781
$*P_{T_{sub-leading jet}}$	45	749	0	464	1.2781
not $\mu^+\mu^-HZZ$	39	275	0	345	1.5366
not vvHZZ	39	275	0	345	1.5366

Table 15: Cut flow table for  $qq\mu\mu\nu\nu$  channel

- <sup>237</sup> The event selection cuts are listed below in sequence.
- $M_{miss} < M_{dimuon}$ : the dimuon invariantmass is greater than the missing mass.
- $35 < N_{pfo} < 100$ : Number of Prticle Flow Objects should be in this range.

•  $75GeV < M_{dijet} < 110GeV$ : the invariant mass of dijet should be in this range.

•  $75GeV < M_{\mu^+\mu^-} < 100GeV$ : the invariant mass of the dimuon should be in this range.

•  $10GeV < M_{visible}^{Recoil} < 50GeV$ : the recoil mass of all visible particles should be in this range.

name	scale	final
e2e2h_bb	0.21896	472
e2e2h_cc	0.011032	7
e2e2h_e3e3	0.023968	1
e2e2h_gg	0.0326888819557	2
e2e2h_ww	0.08176	199
e2e2h_zz	0.010024	39
e3e3h_zz	0.009968099681	1
qqh_e3e3	0.4844	18
qqh_ww	1.6464	3
qqh_zz	0.20216	2
zz_sl0mu_up	1.09032214858	135
zz_sl0mu_down	1.08025726079	324
zz_sl0tau_up	1.10880522921	2
zz_sl0tau_down	1.10887174477	2
ww_s10muq	1.10890944134	1

Table 16: Remained backgrounds (more than 1 event) after all of cuts applied.



Figure 53: Missing mass vs dimuon invariant mass.



Figure 54: Number of PFOs.



Figure 55: Invariant mass of di-jets.



Figure 56: Invariant mass of di-muons.



Figure 57: Recoil mass of visible particles.



Figure 58: All visible particle  $\cos \theta$ 



Figure 59: Minimum angle between the two  $Z(Z^*)$  reconstructed by leptons and jets.

- $-0.95 < cos_{plain} < 0.95$ : Cos calculated by all visible particle Pz and Py should be in this range
- $120 < Min \ angle < 170^{\circ}$ : Minimum angle between the two Z(Z\*) reconstructed by leptons and jets should be within this range.



Figure 60: Recoil mass of di-muons.

- $115GeV < M_{Recoil}^{dimuon} < 155GeV$ : the recoil mass of the dimuon should be in this range.
- $110GeV < M_{Recoil}^{dijet} < 140GeV$ : the recoil mass of the dijet should be in this range.
- $185GeV < M_{visible} < 215GeV$ : the visible mass of all particles should be in this range.
- <sup>249</sup> Two additional cuts:
- $M_{dimuon}^{rec} < 122 GeV \text{ or } M_{dimuon}^{rec} > 128 GeV$ : To avoid the overlap events with  $\mu\mu$ HZZ signals.
- $M_{visible} < 122 GeV \text{ or } M_{visible} > 128 GeV$ : To remove the overlap events with vvHZZ signals.



Figure 61: Recoil mass of di-jets.



Figure 62: Visible mass of all particles.



Figure 63: Distribution of the recoil mass of dijet, after all of cuts applied.

### 252 7 Result

- **7.1** Final Higgs mass distributions and fitting results.
- 254 **7.1.1** μμννqq channel



Figure 64: Final Higgs mass distribution Figure 65: Fit result of  $\mu\mu\nu\nu\eta q$  (cutof  $\mu\mu\nu\nu\eta q$  (cut-based).



Figure 66: Final Higgs mass distribution Figure 67: Fit result of  $\mu\mu qq\nu\nu$  (cutof  $\mu\mu qq\nu\nu$  (cut-based).



Figure 68: Final Higgs mass distribution Figure 69: Fit result of  $vv\mu\mu qq$  (cutof  $vv\mu\mu qq$  (cut-based).



Figure 70: Final Higgs mass distribution Figure 71: Fit result of  $vvqq\mu\mu$  (cutof  $vvqq\mu\mu$  (cut-based).



Figure 72: Final Higgs mass distribution Figure 73: Fit result of  $qq\mu\mu\nu\nu$  (cutof  $qq\mu\mu\nu\nu$  (cut-based).



Figure 74: Final Higgs mass distribution Figure 75: Fit result of  $qqvv\mu\mu$  (cutof  $qqvv\mu\mu$  (cut-based).

- 260 7.2 Calculations
- 261 7.2.1 Cut based calculations

According to the fit results,

precision of 
$$\sigma_{ZH} * BR_{signal}$$
:  $\frac{\Delta \sigma_{ZH} * BR_{signal}}{\sigma_{ZH} * BR_{signal}}$ 

is:

<i>For μμννqq</i> : 18.146%
<i>For µµqqvv</i> : 65.2495%
<i>For vvµµqq</i> : 13.4518%
<i>For ννqqμμ</i> : 27.8294%
<i>For qqµµvv</i> : 63.9272%
<i>For qqvvμμ</i> : 54.256%

Branch ratio of Higgs to ZZ is

 $\frac{N_{signal}}{L\sigma_{ZH}Br_{Z\to\mu\mu}Br_{Z\to\nu\nu}Br_{Z\to jj}\epsilon}$ 

Precision of Branch ratio of Higgs to ZZ is:

 For μμννqq : 18.146%

 For μμqqvv : 65.2495%

 For ννμμqq : 13.4518%

 For ννqqμμ : 27.8294%

 For qqμμνν : 63.9272%

 For qqvvμμ : 54.256%

Combine results of Precision of Branch ratio of Higgs to ZZ is:

9.6762%

Equations used for calculation of precision of Higgs width:

$$\Gamma_{H} = \frac{\Gamma_{H->ZZ^{*}}}{Br_{H->ZZ^{*}}} \propto \frac{\sigma_{ZH}}{Br_{H->ZZ^{*}}}$$
Precision of  $\Gamma_{H} : \frac{\Delta\Gamma_{H}}{\Gamma_{H}} = \sqrt{(\frac{\Delta\sigma_{ZH}}{\sigma_{ZH}})^{2} + (\frac{\Delta Br_{H->ZZ^{*}}}{Br_{H->ZZ^{*}}})^{2}}$ 

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